

**DPMJET version II.5**  
**Sampling of hadron–hadron, hadron-nucleus**  
**and nucleus-nucleus interactions**  
**at accelerator and Cosmic Ray energies**  
**according to the two–component Dual Parton Model**  
**Code manual**

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(February 1, 2008)

The physics of DPMJET-II.5 is described in a companion paper [1]. DPMJET samples hadron–hadron, hadron–nucleus, nucleus–nucleus and neutrino–nucleus interactions at high energies. The two–component Dual Parton Model is used with multiple soft chains and multiple minijets at each elementary interaction. Particle production is realized by the fragmentation of colorless parton–parton chains constructed from the quark content of the interacting hadrons. DPMJET-II.5 includes the cascading of secondaries within the target as well as projectile nuclei which is suppressed by the formation time concept. The excitation energy of the remaining target and projectile nuclei is calculated and using this nuclear evaporation is included into the model. At lab energies below 3 – 5 *GeV* hadron–nucleus collisions are described within the conventional formation zone intranuclear cascade picture; thus the model may be applied down to such energies. It is possible to use the model up to primary energies of  $10^{21}$  eV (per nucleon) in the lab. frame.

DPMJET can also be applied to neutrino nucleus collisions. It extends the neutrino–nucleon models qel (quasi elastic neutrino interactions) and lepto (deep inelastic neutrino nucleon collisions) to neutrino collisions on nuclear targets.

Siegen preprint SI-99-6

## I. PROGRAM SUMMARY

Title of the program:	DPMJET-II.5
Computer:	UNIX Workstations, LINUX-PC's
Program language:	FORTRAN-77
Number of program lines:	about 80,000 (in addition the Lund codes linked)
Other programs called: (included in DPMJET in modified form)	By DPMJET-II.5  DIAGEN [2] Sampling of configurations for nucleus-nucleus interactions within the Glauber formalism DECAY [3] Sampling the decay of hadron resonances. HADRIN [4] Sampling hadron-nucleon interactions below 5 GeV. parts of DTUJET [5,6] Sampling of minijets and multiple soft chains. parts of FLUKA [7] Nuclear evaporation and residual nucleus module. qel [8] Quasi elastic neutrino-nucleon interaction. PYTHIA-6.1 [9] Sampling the hadronization of strings according to the Lund model [9] (Double precision version of JETSET ) lepto-6.5 [10] Deep inelastic neutrino-nucleon interaction. Note: lepto-6.5 uses the single precision JETSET-7.4.
Other programs called:	
Method of solution:	Monte Carlo event generator.

## II. DESCRIPTION OF THE PROGRAM DPMJET-II.5

The basic event generating unit of the code is the subroutine KKINC. Each call of this routine samples one inelastic hadron–nucleus or nucleus–nucleus interaction. Use and necessary initializations are described first in this section; a test program provided with the program package demonstrates the potential application. In the following subsection we discuss important model parameters and define their location in the code for potential user access. The basic structure of the supplied code is described in further subsections.

### A. The event generator and its initialization

As already mentioned the code DPMJET-II.5 uses several other programs. The initialization of the **DECAY** [3] and **HADRIN** [4] codes requires *one single call* of the subroutines DPRIBL, DDATAR, DCHANT, DCHANH and DHADDE.

Calls to PRBLM2 and JDTU initialize the multi–Pomeron sampling and the sampling of minijets like in the DTUJET–99 code (similar to DTUJET–93 [5,6]).

A call to PYINIT initializes the PYTHIA–6.1 sampling of chain decay.

Further initializations and parameter definitions are provided in the routine DMINIT, via the named BLOCK DATA BLKDT1 and the subroutine DEFAUL(EPN,PPN), which has to be called before event generation, too. Besides other initializations this routine sets the parameters, characterizing the type of the actual interaction, for  $\pi^+Cu$  collisions at 200 GeV; EPN and PPN (output variables) give energy and momentum in the lab–system. Actual predefinition and locations of those parameters which might be changed potentially by the user are discussed in the following subsection.

Basic information for the application of the Glauber formalism according to the code **DIAGEN** [2] is generated by the subroutine

SHMAKI (IP, IPZ, IT, ITZ, RPROJ, RTARG, PPN)

which requires the following input parameters defining the actual interaction:

**IP, IPZ:** nucleon number/atomic number of the projectile nucleus; set IP=IPZ=1 for incident hadrons;

**IT, ITZ:** nucleon number/atomic number of the target nucleus;

**PPN:** projectile momentum in GeV/c (per nucleon)

Since the calculations performed by SHMAKI are time consuming, in particular for heavy target nuclei, and in general have to be repeated for each different reaction type and energy, resp., the test program provided offers an option to prepare a data file 'GLAUBTAR.DAT' containing the necessary information for hadron–nucleus and nucleus–nucleus interactions to be considered. This file may be generated in a separate run of the test program using the option 'GLAUBERI' and GLAUBERA, compare Appendix A. The information from this file is read for a given projectile (projectile nucleus) (IP,IPZ) and target nucleus (IT, ITZ) by means of a subroutine call

CALL SHMAKF(IP,IPZ,IT,ITZ).

For the use of different target materials and or different projectiles in one calculation SHMAKF has to be called subsequently with the corresponding parameters (IP,IPZ,IT,ITZ). The information read from the file 'GLAUBTAR.DAT' is numbered internally by the index KKMAT=1,2,... according to the sequence of SHMAKF calls; up to 50 materials may be stored in the standard version of the program. If a larger number of materials is to be used the corresponding dimension in the common /DTUMAT/ has to be increased. (If the required data are not found in the file 'GLAUBTAR.DAT' the execution is stopped.)

After these initializations each call of the subroutine

KKINC (EPN, IT, ITZ, IP, IPZ, IPROJ, KKMAT, ITARG, NHKKH1, IREJ)

generates a single event. The input parameters not yet described have the following meaning:

**IPROJ:** projectile type for hadron–nucleus collisions;

DPMJET-II.5 uses the naming and internal numbering conventions from the BAMJET [11,12] and DECAY [3] codes which are listed in Table A–2 of Appendix A.1;

**ITARG:** Target type for hadron–hadron collisions;

DPMJET-II.5 uses the naming and internal numbering conventions from the BAMJET [11,12] and DECAY [3] codes which are listed in Table A–2 of Appendix A.1;

**KKMAT:** controls the access of the event generator to the information on the Glauber formalism:

KKMAT=0 : Glauber data expected from SHMAKI calculation;

KKMAT>0 : Glauber data expected from the KKMAT'th call of the subroutine SHMAKF.

**NHKKH1:** gives the position in the event COMMON HKKEVT, after which the final state particles are recorded.

**IREJ:** IREJ = 1 indicates, that the event has been rejected  
IREJ = 0 indicates, that the event is fine.

If DPMJET-II.5 is used as event generator in a hadron cascade code, it is practical to write an interface routine. For the use of DPMJET-II.4 in the Cosmic Ray cascade code HEMAS-DPM [13,14] there exists such an interface. DPMJET-II.4 has also been included into the CORSIKA code of Karlsruhe [15].

The following commands will cause the generator to sample one inelastic  $\pi^+Cu$  event at 200 GeV laboratory energy:

```
CALL DMINIT(NCASES,EPN,PPN,NCOUNT,IGLAUB)
```

All of the following down to CALL SAMPPT is usually done within DMINIT

```
*** DECAY initialization
    CALL DDATAR
    CALL DCHANT
*** HADRIN initialization
    CALL DHADDE
    CALL DCHANH
*** setting default parameters
    CALL DEFAUL(EPN,PPN)
    CALL DEFAUX(EPN,PPN)
*** JETSET initialization
    CALL LUNDIN
*** initialization of the random number generator supplied with DPMJET--II.5
    CALL RNDMST(12,34,56,78)
*** initialization for the Glauber formalism by explicit calculation
*** for the actual reaction (projectile/target/energy = pi+/Cu/200 GeV)
    IP=1
    IPZ=1
    IT=64
    ITZ=29
    PPN=200.
    CALL SHMAKI(IP,IPZ,IT,ITZ,RPROJ,RTARG,PPN)
*** sampling of 1 event (pi+ has type IPROJ=13)
    IPROJ=13
    KKMAT=0
*** initialization of the evaporation module
    CALL BERTTP
    CALL INCINI
*** initialization of the unitarization
    CALL PRBLM2(CMENER)
*** initialization of the hard scattering
    CALL JTDTU(0)
*** initialization of the transverse momenta for soft scattering
    CALL SAMPPT(0,PT)

*** generating one event
    CALL KKINC(EPN,IT,ITZ,IP,IPZ,IPROJ,KKMAT)}
    STOP
```

To use the information from the file 'GLAUBTAR.DAT' one has to call SHMAKF instead of SHMAKI and define KKMAT=1.

## B. Information on the final state particles

During the generation of single events several entries are scored in the common blocks /HKKEVT/ and /EXTEVT/ characterizing subsequent stages of the sampling process: Information on initial state nucleons as well as on interacting partons and constructed parton chains, decaying resonances and final state particles is stored into these common blocks. It has the following structure, completely defined in Appendix B:

```
PARAMETER (NMXHKK=.....)
      COMMON /HKKEVT/ NHKK,NEVHKK,ISTHKK(NMXHKK),IDHKK(NMXHKK),
&
      JMOHKK(2,NMXHKK),JDAHKK(2,NMXHKK),
&
      PHKK(5,NMXHKK),VHKK(4,NMXHKK),WHKK(4,NMXHKK)
      COMMON /EXTEVT/ IDRES(NMXHKK),IDXRES(NMXHKK),NOBAM(NMXHKK),
&
      IDBAM(NMXHKK),IDCH(NMXHKK),NPOINT(10)
```

The entries are characterized by their status ISTHKK and type IDHKK as well as by the 4-momenta PHKK; additional pointers define 'parents' and 'daughters' of the actual entry. Final state particles are identified by their status ISTHKK(*i*)=1, -1 or 1001. Resonances, which have decayed are available with ISTHKK(*i*)=2.

The structure of this common block closely follows the suggestions of Ref. [16,17]; conventions for the description of the event history are described in some detail in Appendix B.2, followed by a sample event in Appendix B.3.

## C. Important parameters of the code

In this subsection we summarize physical meaning and location of those parameters which may have a significant influence on observable quantities.

### Sampling of x-values for partons

Parton x-values for a given hadron are sampled from distributions of the general form

$$q(x) \propto x^{-\alpha}(1-x)^{\beta},$$

subject to the requirement that their sum is equal to one. The user has access to the  $\beta$ -parameters for valence quarks which have, however, only minor influence on the final results. They are set to the following default values:

$$\beta_v^{nuc} = 3.5, \quad \beta_v^{mes} = 1.5;$$

for reasons of an optimal sampling efficiency  $\beta_{sea} \equiv 0.0$ . From standard Regge arguments the power in x is fixed to be  $\alpha^{sea} = 0.5$  and  $\alpha^{val} = 0.5$  for sea and valence quarks, respectively.

Additionally, the x-values for partons of colliding projectile and target hadrons are correlated by the interaction mechanism within the DTU model: The constructed color-neutral parton-parton systems (chains) should acquire at least some minimum mass  $M_{min}$  to allow the fragmentation into final state hadrons,

$$M^2 \simeq x^{target} \cdot x^{project} \cdot s \geq M_{min}^2;$$

otherwise the collision numbers sampled according to the Glauber formalism may be strongly biased. Therefore, lower cuts are defined for the sampling of x-values,  $x^{min} = C/\sqrt{s}$ , differing for valence quarks, diquarks and sea quarks, resp. To ensure minimum chain masses for valence-valence (v-v) systems the following values are set by default within DPMJET-II.5:

$$C_q^{val} = 1.8, \quad C_{qq}^{val} = 2.0, \quad C_{q/\bar{q}}^{sea} = 0.5$$

However, since these cuts are imposed for both the projectile and the target independently, lower (but still kinematically allowed) chain masses tend to be suppressed at least for v-v systems. All the user accessible parameters discussed so far are located in the common block

```
COMMON /XSEADI/ XSEACU,UNON,UNOM,UNOSEA, CVQ,CDQ,CSEA,SSMIMA,
+
      SSMIMQ,VVMTHR
```

with the following assignments:

$$\begin{array}{lll} \beta_v^{nuc} = \text{UNON} & \beta_v^{mes} = \text{UNOM} & \\ C_q^{val} = \text{CVQ} & C_{qq}^{val} = \text{CDQ} & C_{q/\bar{q}}^{sea} = \text{CSEA} \\ M_{ss}^{min} = \text{SSMIMA} & (M_{ss}^{min})^2 = \text{SSMIMQ} & M_{vv}^{thr} = \text{VVMTHR} \end{array}$$

### Generation of transverse momenta for secondary hadrons

In the model there are two sources of transverse momenta for created secondaries. First the partons acquire an internal  $p_{\perp}$  which is taken into account in the construction of parton-parton chains. The subsequent hadronization

of the partonic chains is modelled by the JETSET code [9] which itself assigns to the created particles transverse momenta with respect to the jet axis.

Internal transverse momenta for partons are sampled within the subroutine SELPT (file dpmnuc3.f) according to the following distribution for the reduced transverse energy  $E_s = E_\perp - m_p$ ,

$$\frac{dn}{dE_s} \propto E_s \exp(-\gamma^2 E_s/2) \quad (2.1)$$

with

$$p_\perp = \sqrt{E_s^2 + 2E_s m_p}, \quad m_p = 0.94 \text{ GeV},$$

where the slope parameter  $\gamma \equiv \text{BB3}$  is defined directly in this routine (default value  $\text{BB3}=6.0$ ). However, in the case of severe kinematical limitations for individual partons/chains this parameter may be modified in the sampling process.

### Intranuclear cascade

There are two important parameters controlling the development of the intranuclear cascade which have been defined in the previous section: The formation time  $\tau_0$  of created secondary hadrons, and the factor  $\alpha_{mod}^F$  scaling the Fermi momenta of nucleons. With increasing  $\tau_0$  the number of cascade generations and the number of low-energy particles will be reduced;  $\alpha_{mod}^F$  provides the possibility for a certain modification of the momentum distribution for low-energy nucleons.

The maximum number of cascade generations KTAUGE (by default 0) has to be reset by the user, since the cascade is switched off by the default KTAUGE=0.

In the code the corresponding parameters are defined in the common blocks

```
COMMON /TAUFO/  TAUFOR,KTAUGE,ITAUVE
COMMON /NUCIMP/ PRMOM(5,248),TAMOM(5,248),... ,
+               PREBIN,TAEBIN,FERMOD,ETACOU
```

where  $\tau_0 \equiv \text{TAUFOR}$  and  $\alpha_{mod}^F \equiv \text{FERMOD}$ . The option ITAUVE determines whether the  $p_\perp$ -dependent definition of the formation time (ITAUVE=1) or the constant value  $\tau_0$  (ITAUVE=2) are used; by default ITAUVE=1 (compare Section 2.2).

### Lund JETSET fragmentation

The chain fragmentation according to the Lund model JETSET contained within PYTHIA-6.1 [9] is customized for the DPMJET-II.5 needs by changing some of the Lund parameters in the initialization routine LUNDIN. More parameters are changed in the routine BAMLUN, where one JETSET fragmentation is called.

In LUNDIN we prevent furthermore the weak decays of all otherwise stable hadrons and the decay of the  $\pi^0$  by setting the corresponding MDCY parameters equal to zero.

### Baryon and strangeness production, Popcorn mechanism:

The popcorn mechanism in JETSET is controlled by the parameter  $p_{dB}$  (default:  $p_{dB} = 0.1$ ).

```
COMMON /POPCOR/ PDB,AJSDEF
```

The parameters for the POPCORSE effect are in the COMMON /POPCCK/ and the parameters for the CASADIQU effect are in the COMMON /CASADI/.

In JETSET  $p_{dB} = 0.$  is used, to switch off the popcorn mechanism.

### Sea SU(3) symmetry:

The parameter  $s^{sea} = \text{SEASQ}$  (default:  $\text{SEASQ} = 0.5$ ) controls the s-quark content at the sea-quark chain ends.

```
COMMON /SEASU3/ SEASQ
```

### Cronin effect:

The parameters MKCRO (default:  $\text{MKCRO} = 1$ ) and CRONCO (default:  $\text{CRONCO} = 0.64$ ) control the multiple scattering of partons within nuclear matter, and thus the Cronin effect.

```
COMMON /CRONIN/ CRONCO,MKCRON
```

MKCRON = 0 switches off the Cronin effect.

CRONCO is the parameter in the parton multiple scattering formula.

## D. Structure of the supplied code

The DPMJET-II.5 standard source code is stored in several FORTRAN files, listed in the following:

- dpm25nuc1.f, dpm25nuc2.f, dpm25nuc3.f, dpm25nuc4.f, dpm25nuc5.f, dpm25nuc6.f, dpm25nuc7.f

These modules contain all subroutines needed to describe the primary interaction according to the DPM as defined in the previous section. This includes the assignment of Fermi momenta to nucleons, construction of chains and monitoring their decay as well as the intranuclear cascade for generated secondaries.

- dpm25hadri.f

Includes the HADRIN [4] routines for event generation in hadron-nucleon collisions below 5 *GeV* as well as routines for the calculation of energy and reaction dependent cross sections.

- dpm25nolib.f

Contains few standard routines usually unaffected by further developments of the code, including the applied random number generator [18].

- dpm25hist.f

Contains a sample histogram routine producing line printer output for average multiplicities, rapidity and pseudorapidity distributions for generated particles. This serves mainly as an example on how to use the DPMJET events and for benchmarking the code when installing it.

- dpm25diff.f

Contains the routines used to call single diffractive particle production.

- pythia61.f

Contains double precision version of JETSET combined with the PYTHIA-6.1 code.

- dpm25evap2.f or dpm25eva.f

Contains the nuclear evaporation module. Please note, that the module dpm25evap2.f and the data file NUCLEAR.BIN can not be obtained from the author of DPMJET-II.5. The permission to use the evaporation module from FLUKA [7] has to be obtained directly from the Authors of FLUKA (Dr. A. Ferrari and Dr. P.R. Sala, CERN, Geneva and INFN, Sezione di Milano, I-20133 Milano, Italy). The dpm25eva.f module contains dummy routines, to enable to run DPMJET-II without changes without the DPMEVAP module. Of course dpm25eva.f performs no evaporation of the residual nucleus.

- dtu25lap.f or dpm25lap.f

Contains the calculation of the minijets.

Using the file dtu25lap.f the initialization of the minijets is done for one energy, given by the input cards. This version is used for stand-alone runs of the code, where each event is called for the same primary energy.

Using the file dpm25lap.f this initialization is done for all energies. This version is suitable to insert DPMJET-II.5 into hadron cascade codes, where each event will be called at a new energy.

- dtu25pom.f or dpm25pom.f

Contains the calculation of multiple chain production according to eikonal unitarization.

Using the file dtu25pom.f the initialization of the two component Dual Parton Model (calculation of the exclusive multi Pomeron distribution) is done for one energy, given by the input cards. This version is used for stand-alone runs of the code, where each event is called for the same primary energy.

Using the file dpm25pom.f this initialization is done for all energies. This version is suitable to insert DPMJET-II.5 into hadron cascade codes, where each event will be called at a new energy.

If the code is run repeatedly, it will be practical, to read these initialization tables, once calculated, from an external file.

- dpm25qelpo.f

Contains the qel code [8] transformed to double precision and modified to use the Fermi momenta of the nucleons from DPMJET.

- leptonew.f (and jetset74ku.f)

Contains the LEPTO-6.5 code [10] in single precision, which uses the single precision jetset74.f.

- dpm25lepto.f

Contains the DPMJET interface to LEPTO-6.5.

- dpm25nonu.f

If DPMJET is to be applied only to hadronic and nuclear collisions, not to neutrino collisions, it is possible to drop the files leptonew.f, jetset74ku.f, dpm25lepto.f and dpm25qelpo.f and link the code instead to dpm25nonu.f, which contains only dummy routines.

### E. External input and output data files used

- GLAUBTAR.DAT, Unit 47

Glauber model data, see input cards GLAUBERI, GLAUBERA.

- NUCLEAR.BIN

Binary file to read in nuclear data for use in the evaporation module.

- qel.evt

Output file for the qel-events without the modifications of these events in DPMJET.

- lepto.evt

Output file for the lepto-events without the modifications of these events in DPMJET.

### F. Sequence of subroutine calls for event generation

1. The generator subroutine KKINC monitors the sampling of a single event by one call of KKEVT, repeated FOZOKA calls and call(s) of the subroutine FICONF.
2. The subroutine KKEVT performs the sampling of the primary projectile-target interaction. This includes
  - sampling of the actual nucleon coordinates and assignment of 'partners' in the  $n$  elementary interactions between  $n_p$  and  $n_t$  nucleons from the projectile and the target, resp., done in SHMAKO [2];
  - sampling of Fermi momenta of all nucleons in colliding nuclei in FER4M;
  - sampling of x-values for the appropriate quark systems (quarks, antiquarks and diquarks, resp.) from the interacting hadrons in the subroutine XKSAMP and assignment of quark flavors in FLKSAM;
  - construction of color neutral parton-parton chains in the subroutines KKEVVV, KKEVSV, KKEVVS, KKEVSS and further similar routines;
  - hadronization of chains via the JETSET code monitored by the subroutine HADRKK;
  - At energies below 3–5 GeV the code HADHAD is called as hadron-hadron event generator interfacing to the HADRIN code [4].
  - Diffractive events are generated using a call to SDIFF.
3. Alternatively the subroutines KKEVNU or KKEVLE treat the first step of the qel or lepto neutrino nucleus scattering.  
finally KKEVT, KKEVNU or KKEVLE returns the control to KKINC.



4. The intranuclear cascade is modeled by subsequent calls of FOZOKA for each secondary which did not leave the interacting nuclei. FOZOKA transports the particle either until the next interaction or until it leaves the nucleus.
5. The Routine FICONF is called to perform the evaporation step.

### **G. The test program DPMJET-II.5**

The event generator itself is supplied together with a test program which may serve as an example for the application of the program. By a call of the subroutine DMINIT (included in the source file dpm25nuc1.f) the main program DPMJET-II.5 does the necessary initializations discussed above. It also allows the definition/modification of model parameters via input options explained in Appendix A.

The sample histogram routine DISTR (source file dpm25hist.f) generates line printer output for average multiplicities, rapidity and pseudorapidity distributions for created particles. The scoring procedure demonstrates how the information on the event history stored in the common /HKKEVT/ may be applied to extract the properties of the final state particles.

### **H. Remarks on the other codes applied in DPMJET-II.5: DIAGEN, DECAY, HADRIN and RNDM**

All the external codes applied are well documented. The generator DIAGEN [2] modified as described in [1] samples configurations for nucleus-nucleus interactions in the framework of the Glauber model, i.e. spatial coordinates of nucleons in projectile and target nuclei, resp., as well as the actual numbers of 'elementary' interactions  $n$ ,  $n_p$  and  $n_t$  (comp. sect. 2). DIAGEN routines are called via SHMAKI (initialization) and SHMAKO (sampling of configurations), both included in the file dpm25nuc7.f.

A modified version of the resonance decay routine is defined by the subroutine DECHKK treating the decay of resonances from the common /HKKEVT/.

The program HADRIN [4] for the description of hadron-nucleon interactions below 5 GeV is well tested against data [19]. In DPMJET-II.5 it is called via the subroutine FHAD (file dpm25hadri.f).

The algorithm applied for the generation of uniform random numbers (function RNDM) was described in ref. [18]. The generated sequence of pseudorandom numbers should be independent of the actual hardware (if a real number has at least 24 significant bits in the internal representation). This generator has a period of about  $2^{144}$ . A few more comments and a test routine are provided in the source file dpm25nulib.f.

### **ACKNOWLEDGEMENTS**

I thank first of all my collaborator Dr. H.-J. Möhring with whom together all previous versions of the code up to DTUNUC-1.03 were developed. The author thanks Y. Shmakov for supplying the DIAGEN code prior to publication. Furthermore, the support of CERN, the Department of Theoretical Physics in Lund, INFN, Sezione di Milano, INFN, LNF Frascati, LAPP Annecy, The University Santiago de Compostela, INFN, Lab. Naz. del Gran Sasso and the University of Siegen where parts of the program were developed is acknowledged. The code in the versions described here was finalized at Siegen. The author acknowledges the fruitful collaborations with P.Aurenche, G.Battistoni, F.Bopp, M.Braun, A. Capella, R.Engel, A.Ferrari, C.Forti, K.Hänßgen, K.Hahn, I.Kawrakov, C.Merino, N.Mokhov, H.J.Möhring, C.Pajares, D.Pertermann, S.Ritter, S.Roesler, P.Sala and J.Tran Thanh Van on the Dual Parton Model in general.

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# **APPENDIX A :** **THE TEST PROGRAM DPMJET-II.5**

The test program demonstrates the application of the event generating routine KKINC and the extraction of information on the produced secondaries from the common block /HKKEVT/ (in the routine DISTR). Furthermore, it allows a simple redefinition of some important model parameters. It may also be used to prepare data files containing reaction specific information needed for the application of the Glauber formalism. In the case of event generation few standard histograms are constructed from sampled events.

All program activities are monitored by input options. Each input option is identified by a code word and either changes the default values of variables and/or demands some action. Tab. 1 summarizes the standard input options. All variables read from the input file have default values.

TABLE I. The most important options read by the subroutine DMINIT

Option	Description
TITLE	next card is the run title
COMMENT	adds comments to the input data stream
PROJPAR	definition of the projectile
TARPAR	definition of the target
GLAUBERI	initialization of the Glauber formalism for hadron–nucleus interactions / data are written on unit 47
GLAUBERA	initialization of the Glauber formalism for nucleus–nucleus interactions / data are written on unit 47
XSECNUC	Calculation of Glauber cross sections
HADRONIZ	selects JETSET fragmentation of chains
ENERGY	beam energy ( $GeV$ ; per nucleon for nuclei)
MOMENTUM	beam momentum ( $GeV/c$ ; per nucleon for nuclei)
CMENERGY	c.m. energy ( $GeV$ per nucleon)
CENTRAL	central A-A collisions forced
TAUFOR	definition of the formation time parameter
SEADISTR	monitors the x-behaviour of the quark distributions
SEAQUARK	monitors the x-behaviour of the sea–quark distributions
SECINTER	demands secondary interactions
SEASU3	defines $s^{sea}$
DIQUARKS	selects sea–diquarks at chain ends
POPCORN	selects the popcorn mechanism
POPCORCK	selects the Capella–Kopeliovich popcorn mechanism
POPCORSE	selects the diquark breaking sea–quark mechanism
CASADIQU	selects Casado diagram
CRONINPT	selects the Cronin effect
XCUTS	monitors cuts for x–sampling
FERMI	monitors assignment of Fermi momenta to nucleons
SINGDIFF	controls the inclusion of single diffractive events
SINGLECH	include Regge (single chain) contribution
EVAPORAT	include nuclear evaporation
RANDOMIZ	reinitialize the RNDM (RM48) random number generator
NOFINALE	Skip routine FICONF, which calculates the residual nuclei
START	start event sampling for h–h, h–A or A–A collisions
NEUTRINO	start event sampling for qel neutrino collisions
LEPTOEVT	start event sampling for lepto neutrino collisions
STOP	stop the run
PARTICLE	print table of available particles and properties
POMTABLE	Write / Read a table for sampling multipomeron events

### A.1: Description of input options and default parameters

**Table A–2**

Particle codes, SDUM is the parameter to be given on the PROJPAR input card. The internal codes and names were originally introduced by the BAMJET [12,11] and DECAY [3] codes. These codes are also used by the FLUKA [7] and DTUJET [5,6] codes. In the output of DPMJET, in COMMON HKKEVT, the particles are characterized with the PDG code, the internal code is given in the EXTEVT common. (Not all particles used internally are given in this Table.)

SDUM	internal code	internal name	particle	PDG number	charge	q1	q2	q3
PROTON	1	P	$p^+$	2212	1	2	2	1
APROTON	2	AP	$\bar{p}^-$	-2212	-1	-2	-2	-1
	3	E-	$e^-$	11	-1	0	0	0
	4	E+	$e^+$	-11	1	0	0	0
	5	NUE	$\nu_e$	12	0	0	0	0
	6	ANUE	$\bar{\nu}_e$	-12	0	0	0	0
	7	GAM	$\gamma$	22	0	0	0	0
NEUTRON	8	NEU	$n^0$	2112	0	2	1	1
ANEUTRON	9	ANEU	$\bar{n}^0$	-2112	0	-2	-1	-1
	10	MUE+	$\mu^+$	-13	1	0	0	0
	11	MUE-	$\mu^-$	13	-1	0	0	0
KAONLONG	12	K0L	$K_L^0$	130	0	0	0	0
PION+	13	PI+	$\pi^+$	211	1	2	-1	0
PION-	14	PI-	$\pi^-$	-211	-1	1	-2	0
KAON+	15	K+	$K^+$	321	1	2	-3	0
KAON-	16	K-	$K^-$	-321	-1	3	-2	0
LAMBDA	17	LAM	$\Lambda^0$	3122	0	0	0	0
ALAMBDA	18	ALAM	$\bar{\Lambda}^0$	-3122	0	0	0	0
KAONSHRT	19	K0S	$K_S^0$	310	0	0	0	0
SIGMA-	20	SIGM-	$\Sigma^-$	3112	-1	1	1	3

SDUM	internal code	internal name	particle	PDG number	charge	q1	q2	q3
SIGMA+	21	SIGM+	$\Sigma^+$	3222	1	2	2	3
SIGMAZER	22	SIGM0	$\Sigma^0$	3212	0	2	1	3
PIZERO	23	PI0	$\pi^0$	111	0	2	-2	0
KAONZERO	24	K0	$K^0$	311	0	1	-3	0
AKAONZER	25	AK0	$\bar{K}^0$	-311	0	3	-1	0
	31	ETA550	$\eta$	221	0	3	-3	0
	32	RHO+77	$\rho^+$	213	1	2	-1	0
	33	RHO077	$\rho^0$	113	0	2	-2	0
	34	RHO-77	$\rho^-$	-213	-1	1	-2	0
	35	OM0783	$\omega$	223	0	0	0	0
	36	K*+892	$K^{*+}$	323	1	2	-3	0
	37	K*0892	$K^{*0}$	313	0	1	-3	0
	38	K*-892	$K^{*-}$	-323	-1	3	-2	0
	39	AK*089	$\bar{K}^{*0}$	-313	0	3	-1	0
	40	KA+125	$K_1^+$	10323	1	0	0	0
	41	KA0125	$K_1^0$	10313	0	0	0	0
	42	KA-125	$K_1^-$	-10323	-1	0	0	0
	43	AKA012	$\bar{K}_1^0$	-10313	0	0	0	0
	48	S+1385	$\Sigma^{*+}$	3224	1	0	0	0
	49	S01385	$\Sigma^{*0}$	3214	0	0	0	0
	50	S-1385	$\Sigma^{*-}$	3114	-1	0	0	0
	53	N*++12	$\Delta^{++}$	2224	2	2	2	2
	54	N*+ 12	$\Delta^+$	2214	1	2	2	1
	55	N*012	$\Delta^0$	2114	0	2	1	1
	56	N*-12	$\Delta^-$	1114	-1	1	1	1
	67	AN-12	$\bar{\Delta}^{--}$	-2224	-2	-2	-2	2
	68	AN*-12	$\bar{\Delta}^-$	-2214	-1	-2	-2	-1
	69	AN*012	$\bar{\Delta}^0$	-2114	0	-2	-1	-1

SDUM	internal code	internal name	particle	PDG number	charge	q1	q2	q3
	70	AN*+12	$\bar{\Delta}^+$	-1114	1	-1	-1	1
	95	ETA*	$\eta'$	331	0	0	0	0
	96	PHI	$\phi$	333	0	3	-3	0
	97	TETA0	$\Xi^0$	3322	0	2	3	3
	98	TETA-	$\Xi^-$	3312	-1	1	3	3
	99	ASIG-	$\bar{\Sigma}^-$	-3222	-1	-2	-2	-3
	100	ASIG0	$\bar{\Sigma}^0$	-3212	0	-2	-1	-3
	101	ASIG+	$\bar{\Sigma}^+$	-3112	1	-1	-1	-3
	102	ATETA0	$\bar{\Xi}^0$	-3322	0	-2	-3	3
	103	ATETA+	$\bar{\Xi}^+$	-3312	1	-1	-3	-3
	104	SIG*+	$\Sigma^{*+}$	3224	1	2	2	3
	105	SIG*0	$\Sigma^{*0}$	3214	0	2	1	3
	106	SIG*-	$\Sigma^{*-}$	3114	-1	1	1	3
	107	TETA*0	$\Xi^{*0}$	3324	0	2	3	3
	108	TETA*	$\Xi^{*-}$	3314	-1	1	3	3
	109	OMEGA-	$\Omega^-$	3334	-1	3	3	3
	110	ASIG*-	$\bar{\Sigma}^{*-}$	-3224	-1	-2	-2	-3
	111	ASIG*0	$\bar{\Sigma}^{*0}$	-3214	0	-2	-1	-3
	112	ASIG*+	$\bar{\Sigma}^{*+}$	-3114	1	-1	-1	-3
	113	ATET*0	$\bar{\Xi}^{*0}$	-3324	0	-2	-3	3
	114	ATET*+	$\bar{\Xi}^{*+}$	-3314	1	-1	-3	3
	115	OMEGA+	$\bar{\Omega}^+$	-3334	1	-3	-3	3
	116	D0	$D^0$	421	0	4	-2	0
	117	D+	$D^+$	411	1	4	-1	0
	118	D-	$D^-$	-411	-1	1	-4	0
	119	AD0	$\bar{D}^0$	-421	0	2	-4	0
	120	DS+	$D_s^+$	431	1	4	-3	0
	121	DS-	$D_s^-$	-431	-1	3	-4	0

SDUM	internal code	internal name	particle	PDG number	charge	q1	q2	q3
	122	ETAC	$\eta_c$	441	0	4	-4	0
	123	D*0	$D^{*0}$	423	0	4	-2	0
	124	D*+	$D^{*+}$	413	1	4	-1	0
	125	D*-	$D^{*-}$	-413	-1	1	-4	0
	126	AD*0	$\bar{D}^{*0}$	-423	0	2	-4	0
	127	DS*+	$D_s^{*+}$	433	1	4	-3	0
	128	DS*-	$D_s^{*-}$	-433	-1	3	-4	0
	129	CHI1C	$\chi_1^c$	20443	0	4	-4	0
	130	JPSI	$J/\psi$	443	0	0	0	0
	131	TAU+	$\tau^+$	-15	1	0	0	0
	132	TAU-	$\tau^-$	15	-1	0	0	0
	133	NUET	$\nu_\tau$	16	0	0	0	0
	134	ANUET	$\bar{\nu}_\tau$	-16	0	0	0	0
	135	NUEM	$\nu_\mu$	14	0	0	0	0
	136	ANUEM	$\bar{\nu}_\mu$	-14	0	0	0	0
	137	LAMC+	$\Lambda_c^+$	4122	1	2	1	4
	138	XIC+	$\Xi_c^+$	4232	1	2	3	4
	139	XIC0	$\Xi_c^0$	4132	0	1	3	4
	140	SIGC++	$\Sigma_c^{++}$	4222	2	2	2	4
	141	SIGC+	$\Sigma_c^+$	4212	1	0	0	0
	142	SIGC0	$\Sigma_c^0$	4112	0	1	1	4
	143	S+	$\Xi_c'^+$	4322	1	0	0	0
	144	S0	$\Xi_c'^0$	4312	0	0	0	0
	145	T0	$\Omega_c^0$	4332	0	3	3	4
	146	XU++	$\Xi_{cc}^{++}$	4422	2	2	4	4
	147	XD+	$\Xi_{cc}^+$	4412	1	1	4	4
	148	XS+	$\Omega_{cc}^+$	4432	1	3	4	4
	149	ALAMC-	$\bar{\Lambda}_c^-$	-4122	1	-2	-1	4

SDUM	internal code	internal name	particle	PDG number	charge	q1	q2	q3
	150	AXIC-	$\bar{\Xi}_c^-$	-4232	1	-2	-3	-4
	151	AXIC0	$\bar{\Xi}_c^0$	-4132	0	-1	-3	-4
	152	ASIGC-	$\bar{\Sigma}_c^{--}$	-4222	-2	-2	-2	-4
	153	ASIGC-	$\bar{\Sigma}_c^-$	-4212	1	0	0	0
	154	ASIGC0	$\bar{\Sigma}_c^0$	-4112	0	-1	-1	-4
	155	AS-	$\bar{\Xi}_c'^-$	-4322	1	0	0	0
	156	AS0	$\bar{\Xi}_c'^0$	-4312	0	0	0	0
	157	AT0	$\bar{\Omega}_c^0$	-4332	0	-3	-3	-4
	158	AXU-	$\bar{\Xi}_{cc}^{--}$	-4422	-2	-2	-4	-4
	159	AXD-	$\bar{\Xi}_{cc}^-$	-4412	1	-1	-4	-4
	160	AXS	$\bar{\Omega}_{cc}^-$	-4432	-1	-3	-4	-4
	161	C1*++	$\Sigma_c^{*++}$	4224	2	2	2	4
	162	C1*+	$\Sigma_c^{*+}$	4214	1	2	1	4
	163	C1*0	$\Sigma_c^{*0}$	4114	0	1	1	4
	164	S*+	$\Xi_c^{*+}$	4324	1	2	3	4
	165	S*0	$\Xi_c^{*0}$	4314	0	1	3	4
	166	T*0	$\Omega_c^{*0}$	4334	0	3	3	4
	167	XU*++	$\Xi_{cc}^{*++}$	4424	2	2	4	4
	168	XD*+	$\Xi_{cc}^{*+}$	4414	1	1	4	4
	169	XS*+	$\Omega_{cc}^{*+}$	4434	1	3	4	4
	170	TETA++	$\Omega_{ccc}^{*++}$	4444	2	4	4	4
	171	AC1*-	$\bar{\Sigma}_c^{*-}$	-4224	2	-2	-2	-4
	172	AC1*-	$\bar{\Sigma}_c^{*-}$	-4214	-1	-2	-1	-4
	173	AC1*0	$\bar{\Sigma}_c^{*0}$	-4114	0	-1	-1	-4
	174	AS*-	$\bar{\Xi}_c^{*-}$	-4324	-1	-2	-3	-4
	175	AS*0	$\bar{\Xi}_c^{*0}$	-4314	0	-1	-3	-4
	176	AT*0	$\bar{\Omega}_c^{*0}$	-4334	0	-3	-3	-4
	177	AXU*-	$\bar{\Xi}_{cc}^{*-}$	-4424	-2	-2	-4	-4
	178	AXD*-	$\bar{\Xi}_{cc}^{*-}$	-4414	1	-1	-4	-4
	179	AXS*-	$\bar{\Omega}_{cc}^{*-}$	-4434	-1	-3	-4	-4
	180	ATET-	$\bar{\Omega}_{ccc}^{*-}$	-4444	-2	-4	-4	-4



All input records of DPMJET-II.5 have the following form:

```
CODEWD, (WHAT(I), I = 1,6), SDUM
FORMAT (A8, 2X, 6E 10.0, A8)
```

In the following we describe the meaning of the corresponding variables for the standard input options in the same order as the code words CODEWD are listed in Tab. A-1.

Please note: further input options are described in the Appendices C and D.

We give also the default values of the parameters .

- Code word = 'TITLE'

This option card must be followed by a card giving a run title, which will be reproduced in the output.

- Code word = 'COMMENT'

This option allows to add comments to the input file at arbitrary positions.

**WHAT(1):** number of comment cards following this card.  
default : 1.0

- Code word = 'PROJPAR'

This card defines the type of the projectile;  
if given it has to be included before the MOMENTUM/ENERGY option(s).

**SDUM:** defines the projectile to be a hadron if given; for naming conventions see Table 2.

If SDUM is given WHAT(1) and WHAT(2) need no specification; for projectile nuclei SDUM has no meaning.

**WHAT(1):** mass number of projectile nucleus - IP

**WHAT(2):** atomic number of projectile nucleus - IPZ

default: incident proton (IP=1, IPZ=1).

- Code word = 'TARPAR'

This card defines the type of the target nucleus.

**WHAT(1):** mass number of projectile nucleus - IT

**WHAT(2):** atomic number of projectile nucleus - ITZ

default: Nitrogen *N* target ( IT=14, ITZ=7 )

- Code word = 'GLAUBERI'

Requests the initialization of the Glauber formalism for hadron-nucleus interactions;

the target nucleus has to be defined by the code word TARPAR in advance;

tables of impact parameter distributions for b-sampling are written to unit 47 for several momenta

( $p_{lab} = \sqrt{10}^{(i+1)}$ ;  $i = 1, \dots, 24$ ) and different projectiles ( $p, \pi^+$ );

WHAT(1) = JGLAUB JGLAUB = 1 Calculation GLAUBTAR.DAT file (default)

- Code word = 'GLAUBERA'

Requests the initialization of the Glauber formalism for nucleus-nucleus interactions;

the target nucleus has to be defined by the code word TARPAR in advance;

the projectile nucleus has to be defined by the code word PROJPAR in advance;

tables of impact parameter distributions for b-sampling are written to unit 47 for several momenta

( $p_{lab} = \sqrt{10}^{(i+1)}$ ;  $i = 1, \dots, 24$ ) and different projectiles ;

WHAT(1) = JGLAUB JGLAUB = 1 Calculation GLAUBTAR.DAT file (default)

- Code word = 'XSECNUC'

Requests the calculation of Glauber cross sections for hadron (nucleus) –nucleus interactions; the target nucleus has to be defined by the code word TARPAN in advance; the projectile nucleus has to be defined by the code word PROJPAR in advance;  
 WHAT(1) = ECMUU lowest CMS energy  
 WHAT(2) = ECMOO highest CMS energy  
 WHAT(3) = NGRITT number of CMS energy points  
 WHAT(4) = NEVTT number of Monte Carlo events for each cross section calculation

- Code word = 'HADRONIZ'

Selects JETSET fragmentation of soft chains

**WHAT(1):** IHADRZ (default: 2)

IHADRZ = 2 selects JETSET fragmentation.

IHADRZ = 11 selects an alternative JETSET fragmentation.

- Code word = 'ENERGY'

This card defines the energy of the projectile in the target rest system. For incident nuclei the energy per nucleon is expected.

NOTE: only one of the ENERGY and the MOMENTUM options is necessary, the last defined option is applied; both these options are to be given after the PROJPAR definition.

**WHAT(1):** projectile energy in *GeV*

- Code word = 'MOMENTUM'

This card defines the momentum of the projectile in the target rest system. For incident nuclei the momentum per nucleon is expected.

NOTE: only one of the ENERGY and the MOMENTUM options is necessary, the last defined option is applied; both these options are to be given after the PROJPAR definition.

**WHAT(1):** projectile momentum in *GeV/c*;

**Default:** 100 000 *GeV/c*

- Code word = 'CMENERGY'

Same as for code word 'ENERGY', but WHAT(1) defines the energy in the hadron/nucleon–nucleon c.m. system.

- Code word = 'CENTRAL'

This code word forces central nucleus-nucleus collisions, i.e. most nucleons of the projectile nucleus are forced to interact. The actual requirement depends on the atomic number of both the projectile and the target nuclei and is defined in the subroutine KKEVT (source file dpm25nuc2.f, after CALL SHMAKO ). Furthermore, the actual impact parameter is set near to zero for this case in subroutine MODB (source file dpm25nuc7.f).

**WHAT(1):** = ICENTR default: 0.0, i.e. no forcing.

ICENTR=0 : normal collisions

ICENTR=1 : central collisions with impact parameter condition in dpm25nuc7.f and NA condition in dpm25nuc2.f

ICENTR=2 : only NA condition in dpm25nuc2.f

ICENTR=3 : less central condition for Pb–Pb

ICENTR=10: peripheral collisions

Please note: The definition of central collisions is not unique, see the actual definitions in routine KKEVT (dpm25nuc2.f and dpm25nuc7.f).

- Code word = 'TAUFOR'

This option defines the formation time parameter controlling the intranuclear cascade. Additionally it allows to restrict the number of generations of secondary cascade interactions.

**WHAT(1):** formation time in  $fm/c$ ;

default: 105  $fm/c$

**WHAT(2):** maximum number of allowed generations of secondary interactions; default: 0

**WHAT(3):** monitors the definition of the formation time actually applied (comp. Subsects. 2.3 and 3.3.3):

WHAT(3)=1 :  $p_{\perp}$ -dependent formation time , (default)

WHAT(3)=2 : constant formation time

Please note, for h-h interactions, one should use  $WHAT(2) = 0$ . ! The default corresponds to a suppression of the formation zone cascade. To apply the formation zone cascade, the recommended values are (TAUFOR 5. 25. 1.).

- Code word = 'SEADISTR'

This option card defines properties of the quark distributions, which are of the general form  $q(x) \propto x^{-\alpha}(1-x)^{\beta}$ .

**WHAT(1):** no meaning,  $\alpha^{sea}$  is now controlled by the SEQUARK card. (default  $\alpha^{sea} = 0.5$ )

default :  $\alpha^{sea} = 1.0$

**WHAT(2):**  $\beta^{nuc}$  for valence-quark distributions of nucleons;

default :  $\beta^{nuc} = 3.5$

**WHAT(3):**  $\beta^{mes}$  for valence-quark distributions of mesons;

default :  $\beta^{mes} = 1.11$

**WHAT(4):** no meaning;

NOTE: for reasons of the sampling efficiency the parameters for the sea distribution are fixed to  $\alpha^{sea}$ =either 1.0 or 0.5 and  $\beta^{sea} = 0.0$  in the present version of the subroutine XKSAMP and cannot be changed easily by the user.

- Code word = 'SEQUARK'

This option card defines properties of the quark distributions, which are of the general form  $q(x) \propto x^{-\alpha}(1-x)^{\beta}$ .

**WHAT(1):**  $\alpha^{sea}$  for sea-quark distributions possible values: 0.5 and 1.;

default :  $\alpha^{sea} = 0.5$

NOTE: for reasons of the sampling efficiency the parameters for the sea distribution are fixed to  $\alpha^{sea}$ =either 1.0 or 0.5 and  $\beta^{sea} = 0.0$  in the present version of the subroutine XKSAMP and cannot be changed easily by the user.

- Code word = 'SECINTER'

This option demands secondary interactions, the use of this option is at present only recommended for heavy ion collisions at SPS energies.

**WHAT(1):** = 1. secondary interactions demanded

default: 0

SECINTER should only be used for heavy ion collisions at CERN-SPS energies.

- Code word = 'SEASU3'

This option determines the strange quark fraction  $s^{sea}$  at the sea-quark chain ends.

**WHAT(1):**  $s^{sea}$ ,

default: 0.5

- Code word = 'DIQUARKS'

This option determines diquarks at sea chain ends

**WHAT(1):** IDIQUA,

default: 1 IDIQUA=0 no diquarks at Glauber sea chain ends

IDIQUA=1 diquarks at Glauber sea chain ends

**WHAT(2):** IDIQUU,  
default: 1 IDIQUU=0 no diquarks at unitary sea chain ends  
IDIQUU=1 diquarks at unitary sea chain ends

**WHAT(3):** AMEDD,  
default: 0.9 1.-AMEDD is the fraction of sea chain ends with a sea-diquark

- Code word = 'POPCORN'

This option determines the popcorn mechanism for JETSET fragmentation.

**WHAT(1):** PDB,  
default: 0.10  
JETSET: PDB gives the fraction of diquarks fragmenting directly into baryons.  
PDB = 0 switches off the popcorn mechanism.

NOTE: POPCORN should appear before the HADRONIZE card.

- Code word = 'POPCORCK'

This option determines the CK (Capella–Kopeliovich) popcorn mechanism for JETSET fragmentation.

**WHAT(1):** IJPOCK,  
default: 0  
IJPOCK=0 switches off the CK popcorn mechanism  
mechanism.

**WHAT(2):** PDBCK,  
default: 0.00  
PDBCK gives the fraction of diquarks with CK mechanism

NOTE: POPCORCK should appear before the HADRONIZE card.

- Code word = 'POPCORSE'

This option determines the CK (Capella–Kopeliovich) popcorn mechanism for JETSET fragmentation.

**WHAT(2):** PDBSE,  
default: 0.45  
PDBSE gives the probability for a diquark to be split by Glauber sea quarks

**WHAT(2):** PDBSEU,  
default: 0.45  
PDBSEU gives the probability for a diquark to be split by unitary sea quarks

NOTE: POPCORSE should appear before the HADRONIZE card.

- Code word = 'CASADIQU'

This option determines the CASADO diagram

**WHAT(1):** ICASAD,  
default: 1  
ICASAD=0 switches off the Casado mechanism  
ICASAD=1 switches on the Casado mechanism

**WHAT(2):** CASAXX,  
default: 0.50  
CASAXX gives the probability for the Casado mechanism

- Code word = 'CRONINPT'

This option determines the Cronin effect.

**WHAT(1):** MKCRON,

default: 1.

MKCRON = 0 switches off the Cronin effect.

**WHAT(2):** CRONCO,

default: 0.64

CRONCO is the parameter in the parton multiple scattering formula.

- Code word = 'XCUTS'

This option redefines the lower cuts for the sampling of x-values to ensure minimum chain masses for hadronization (used in XKSAMP).

**WHAT(1)** = CVQ ;  $(x_q^{val})^{min} = CVQ/\sqrt{s}$ ,

lower cut for valence quarks; default : CVQ = 1.8

**WHAT(2)** = CDQ ;  $(x_{qq}^{val})^{min} = CDQ/\sqrt{s}$ ,

lower cut for valence diquarks; default : CDQ = 2.0

**WHAT(3)** = CSEA;  $(x_{q/\bar{q}}^{sea})^{min} = CSEA/\sqrt{s}$ ,

lower cut for sea quarks; default : CSEA = 0.5

**WHAT(4)** = SSMIMA;  $(x_{q/\bar{q}}^{sea})^{target} \cdot (x_{q/\bar{q}}^{sea})^{project.} \cdot s \geq (SSMIMA)^2$ ,

lower cut for the mass of sea-sea chains applied in XKSAMP;

default : SSMIMA = 1.2 GeV.

- Code word = 'FERMI'

**WHAT(1):** Inclusion of Fermi momenta for nucleons if WHAT(1)= 1.0 (default)

**WHAT(2):** FERMOD - scale factor for Fermi momentum as calculated from zero temperature Fermi distribution of nucleons;

default: FERMOD = 0.6.

**WHAT(3):** use zero temperature Fermi momentum distribution if WHAT(3)= 1.0 (default); use distribution according to Ref. [20] for WHAT(3)=2.

- Code word = 'SINGDIFF'

This option controls the generation of single diffractive events.

**WHAT(1):** ISINGD;

ISINGD=1: Single diffraction included,

ISINGD=0: Single diffraction suppressed,

ISINGD=2: Only single diffraction,

ISINGD=3: Only single diffraction, target excited,

ISINGD=4: Only single diffraction, projectile excited.

default: 1

- Code word = 'SINGLECH'

**WHAT(1):** ISICHA;

ISINGD=1: include Regge (single chain) contributions,

ISINGD=0: single chains suppressed,

ISINGD=2: Only single contribution,

default: 0

Please note: The single chain (Regge) contributions are only essential at low energies. they are at present only implemented for antibaryon and meson projectiles.

- Code word = 'EVAPORAT'

Evaporation is performed if the EVAPORAT card is present Default:IEVAP=0 No evaporation

**what (1)** = IEVAP

IEVAP = 1: evaporation is performed

IEVAP = 0: no evaporation

Actually the EVAPORAT card allows for more options, which normally are not needed by the user. See the description in dpm25nuc1.f.

- Code word = 'RANDOMIZ'

Re-initialization of RNDM (RM48) random number generator Default: standard initialization  
ISEED1 and ISEED2 are printed at the end of each DPMJET run. They can also be generated by a RD2OUT call (AUAU=RD2OUT(ISEED1, ISEED2))

**what (1)** = ISEED1

**what (2)** = ISEED2

- Code word = 'NOFINALE'

This option skips the call of the routine FICONF, for instance in heavy ion collisions;

**WHAT(I) = 1.** : no FICONF call, Default: 0.:

- Code word = 'START'

This option starts the generation of events in h-h, h-A and A-A collisions including the output of standard histograms.

**WHAT(1):** number of events to be sampled; default: 100

**WHAT(2):** the Glauber initialization is forced to be calculated in SHMAKI,  
i.e. no data read from file GLAUBTAR.DAT, if **WHAT(2) = 1.0**

- Code word = 'NEUTRINO'

This option starts the generation of events for quasi elastic (qel) neutrino-nucleus collisions including the output of standard histograms.

**WHAT(1):** number of events to be sampled; default: 100

**WHAT(2):** neutrino type as defined in qel (1= $\nu_e$ , 2= $\bar{\nu}_e$ , 3= $\nu_\mu$ , 4= $\bar{\nu}_\mu$ , 5= $\nu_\tau$ , 6= $\bar{\nu}_\tau$ )

- Code word = 'LEPTOEVT'

This option starts the generation of events for deep inelastic (lepto) neutrino-nucleus collisions including the output of standard histograms.

**WHAT(1):** number of events to be sampled; default: 100

**WHAT(2):** neutrino type as defined in lepto (12= $\nu_e$ , -12= $\bar{\nu}_e$ , 14= $\nu_\mu$ , -14= $\bar{\nu}_\mu$ )

- Code word = 'STOP'

This option stops the execution of the program.

- Code word = 'PARTICLE'

This card triggers a printout of all the particles defined in the BAMJET-DECAY chain fragmentation, including name conventions, quantum numbers and decay channels. This are the internal particle codes used in DPMJET.

- Code word = 'POMTABLE'

Only if the files dpm25pom.f and dpm25lap.f are linked instead of the files dtu25pom.f and dtu25lap.f.

**WHAT(1):** 0 ( default) the file pomtab.dat is written. :1 The file pomtab.dat is read.

## A.2: Sample Input

In the following several typical examples of input data are reproduced. We give only the input cards which change the default parameters.

One of the examples demonstrates the use of the test program to generate the input data for the Glauber formalism (file GLAUBTAR.DAT) in  $A$ - $N$  collisions.

### 1. Hadron-Hadron collisions

Note: SINGDIFF includes diffractive events. XCUTS slightly changes some defaults.

```

TITLE
DPMJET p-p 200 GeV LAB w. Diffr.
PROJPAR                                     PROTON
TARPAR          1.0          1.
MOMENTUM 200.
SINGDIFF        1.
XCUTS           0.70        2.0        0.30        1.201
START          1000000.        1.
STOP

```

### Hadron-Nucleus collisions

Note: Here the NOFINALE and EVAPORATE options assure evaporation and the working out of the residual nucleus. If this is required, then also the TAUFOR card is needed in a form as given to perform the FZIC. In hadron-nucleus collisions diffractive events might be demanded like in the example or might be suppressed.

```

TITLE
DPMJET p-N 100000 GeV CMS w. Diffr.
PROJPAR                                     PROTON
TARPAR          14.0          7.
CMENERGY 100000.
NOFINALE        0.
EVAPORATE       1.
TAUFOR           5.0          25.
SINGDIFF        1.
START          50000.          1.
STOP

```

### Minimum bias nucleus-nucleus collisions

Note: Here again the NOFINALE and EVAPORATE options assure evaporation and the working out of the residual nuclei. If this is required, then also the TAUFOR card is needed in a form as given to perform the FZIC. In nucleus-nucleus collisions diffractive events might be demanded or might be suppressed like in the example. In very high energy nucleus-nucleus collisions the code might run more stable if the Cronin effect is suppressed like in the example given.

```

TITLE
DPMJET Fe-N 10 TeV CMS without Diffr.
PROJPAR          56.          26.
TARPAR          14.0          7.

```

```

CMENERGY 10000.
NOFINALE 0.
EVAPORATE 1.
TAUFOR 5. 25.
SINGDIFF 0.
CRONINPT 0. 0.00
START 10000. 1.
STOP

```

*Central Nucleus-Nucleus collisions*

Note: In central nucleus-nucleus collisions diffractive events should always be excluded like in the examples given. In both examples the FZIC and evaporation is demanded (TAUFOR, NOFINALE, EVAPORATE options) It is also possible to run nucleus-nucleus collisions without FZIC and evaporation. The last parameter on the XCUTS card is convenient to tune somewhat the secondary particle multiplicity in nucleus-nucleus collisions.

```

TITLE
DPMJET central S-S 200GeV LAB with secondary interactions
PROJPAR
PROJPAR 32.0 16.
TARPAR 32.0 16.
MOMENTUM 200.
NOFINALE 0.
EVAPORATE 1.
TAUFOR 5.0 25.
SECINTER 1.
CENTRAL 2.
SINGDIFF 0.
CRONINPT 0. 0.00
XCUTS 1.80 2.0 0.50 2.50
START 10000. 1.
STOP

```

```

TITLE
DPMJET central Pb-Pb 158 GeV LAB with secondary interaction
PROJPAR 207.0 82.
TARPAR 207.0 82.
MOMENTUM 158.
NOFINALE 0.
EVAPORATE 1.
TAUFOR 5.0 25.
SECINTER 1.
CENTRAL 2.
SINGDIFF 0.
CRONINPT 1. 0.64
XCUTS 1.00 2.0 0.50 2.50
START 1000. 0.
STOP

```



*Cross section calculation*

```
TITLE
DPMJET p-Ar XSEC
PROJPAR
TARPAR      40.0      18.
XSECNUC      2. 1000000.    50.    2000.
STOP
```

PROTON

```
TITLE
DPMJET Fe-N XSEC
PROJPAR
PROJPAR      56.0      26.
TARPAR      14.0      7.
XSECNUC      2. 1000000.    50.    20000.
STOP
```

PROTON

*Input data for Glauber formalism*

```
TITLE
DPMJET-II Prepare Glauber data for different nucleus-N collisions
PROJPAR      1.      1.
TARPAR      14.0      7.
GLAUBERI
PROJPAR      4.      2.
TARPAR      14.0      7.
GLAUBERA
PROJPAR      12.      6.
TARPAR      14.0      7.
GLAUBERA
PROJPAR      14.      7.
TARPAR      14.0      7.
GLAUBERA
PROJPAR      24.      12.
TARPAR      14.0      7.
GLAUBERA
PROJPAR      28.      14.
TARPAR      14.0      7.
GLAUBERA
PROJPAR      40.      20.
TARPAR      14.0      7.
GLAUBERA
PROJPAR      48.      22.
TARPAR      14.0      7.
GLAUBERA
PROJPAR      56.0      26.
TARPAR      14.0      7.
GLAUBERA
STOP
```

Please note: DPMJET does not consider neutrinos as projectile particles, therefore, we use PROJPAR = PROTON.  
This is of course not used later on.

```
TITLE
DPMJET-II.5 5 GeV Neutrino(nu-e)-Ar  quasi-elastic interaction
PROJPAR                                           PROTON
TARPAR      40.0      18.
MOMENTUM      5.
NOFINALE      0.
EVAPORATE      1.
TAUFOR      5.0      25.
NEUTRINO    1000.      1.
STOP
```

Please note: DPMJET does not consider neutrinos as projectile particles, therefore, we use PROJPAR = PROTON.  
This is of course not used later on.

*Deep inelastic (lepto) neutrino-nucleus interaction in DPMJET-II.5*

```
TITLE
DPMJET Deep inelastic Neutrino(nu-e)-Ar using lepto
PROJPAR                                           PROTON
TARPAR      40.0      18.
MOMENTUM      50.
NOFINALE      0.
EVAPORATE      1.
TAUFOR      5.0      25.
LEPTOEVT    1000.      12.
STOP
```

## APPENDIX B : EVENT HISTORY AND THE COMMON BLOCKS /HKKEVT/ AND /EXTEVT/

### B.1: Structure of the common blocks

During the generation of individual events several entries are scored in the common blocks /HKKEVT/ and /EXTEVT/ characterizing subsequent stages of the sampling process. Scored entries are, for instance, initial state nucleons, partons and parton chains, decaying resonances as well as final state particles. These entries are characterized by their type, 4-momenta and coordinates; additional pointers define 'parents' and 'daughters' of the actual entry (if any). The structure of the /HKKEVT/ common block closely follows the suggestions of Ref. [16,17]. Within the code there are extensive comments explaining the variables used in this common block. Below the common blocks are reproduced together with these comments.

Note that for interactions potentially resulting in high multiplicities of secondaries (i.e. very high energies and/or heavy ion-ion collisions) it may become necessary to increase the dimension NMXHKK, the maximum number of entries for a given event.

```

PARAMETER (NMXHKK=49998)
COMMON /HKKEVT/ NHKK,NEVHKK,ISTHKK(NMXHKK),IDHKK(NMXHKK),
&                JMOHKK(2,NMXHKK),JDAHKK(2,NMXHKK),
&                PHKK(5,NMXHKK),VHKK(4,NMXHKK),WHKK(4,NMXHKK)
COMMON /EXTEVT/ IDRES(NMXHKK),IDXRES(NMXHKK),NOBAM(NMXHKK),
&                IDBAM(NMXHKK),IDCH(NMXHKK),NPOINT(10)

```

```

C
C Based on the proposed standard COMMON block (Sjostrand Memo 17.3,89)
C
C NMXHKK: maximum numbers of entries (partons/particles) that can be
C   stored in the common block.
C
C NHKK: the actual number of entries stored in current event. These are
C   found in the first NHKK positions of the respective arrays below.
C   Index IHKK, 1 <= IHKK <= NHKK, is used below to denote a given
C   entry.
C
C ISTHKK(IHKK): status code for entry IHKK, with following meanings:
C   = 0 : null entry.
C   = 1 : an existing entry, which has not decayed or fragmented.
C         This is the main class of entries which represents the
C         "final state" given by the generator.
C   = 2 : an entry which has decayed or fragmented and therefore
C         is not appearing in the final state, but is retained for
C         event history information.
C   = 3 : a documentation line, defined separately from the event
C         history. (incoming reacting
C         particles, etc.)
C   = 4 - 10 : undefined, but reserved for future standards.
C   = 11 - 20 : at the disposal of each model builder for constructs
C               specific to his program, but equivalent to a null line in the
C               context of any other program. One example is the cone defining
C               vector of HERWIG, another cluster or event axes of the JETSET
C               analysis routines.
C   = 21 - : at the disposal of users, in particular for event tracking
C             in the detector.
C
C IDHKK(IHKK) : particle identity, according to the Particle Data Group
C   standard.
C
C JMOHKK(1,IHKK) : pointer to the position where the mother is stored.
C   The value is 0 for initial entries.

```

C  
C JMOHKK(2,IHKK) : pointer to position of second mother. Normally only  
C one mother exist, in which case the value 0 is used. In cluster  
C fragmentation models, the two mothers would correspond to the q  
C and qbar which join to form a cluster. In string fragmentation,  
C the two mothers of a particle produced in the fragmentation would  
C be the two endpoints of the string (with the range in between  
C implied).  
C  
C JDAHKK(1,IHKK) : pointer to the position of the first daughter. If an  
C entry has not decayed, this is 0.  
C  
C JDAHKK(2,IHKK) : pointer to the position of the last daughter. If an  
C entry has not decayed, this is 0. It is assumed that the daughters  
C of a particle (or cluster or string) are stored sequentially, so  
C that the whole range JDAHKK(1,IHKK) - JDAHKK(2,IHKK) contains  
C daughters. Even in cases where only one daughter is defined (e.g.  
C K0 -> K0S) both values should be defined, to make for a uniform  
C approach in terms of loop constructions.  
C  
C PHKK(1,IHKK) : momentum in the x direction, in GeV/c.  
C PHKK(2,IHKK) : momentum in the y direction, in GeV/c.  
C PHKK(3,IHKK) : momentum in the z direction, in GeV/c.  
C PHKK(4,IHKK) : energy, in GeV.  
C PHKK(5,IHKK) : mass, in GeV/c\*\*2. For spacelike partons, it is allowed  
C to use a negative mass, according to PHKK(5,IHKK) = -sqrt(-m\*\*2).  
C  
C VHKK(1,IHKK) : production vertex x position, in mm.  
C VHKK(2,IHKK) : production vertex y position, in mm.  
C VHKK(3,IHKK) : production vertex z position, in mm.  
C VHKK(4,IHKK) : production time, in mm/c (= 3.33\*10\*\*(-12) s).  
C  
C WHKK(I,IHKK) gives positions and times in projectile frame,  
C the chains are created on the positions of the projectile nucleons  
C in the projectile frame (target nucleons in target frame);  
C both positions are therefore not completely consistent.  
C The times in the projectile frame ,however, are obtained by  
C a Lorentz transformtion from the lab system.  
C  
C Entries to the /EXTEVT/ COMMON block  
C  
C IDRES(IHKK) gives the Mass number A in case of nuclear  
C fragments or residual nuclei (IDHKK(IHKK)=80000)  
C  
C IDXRES(IHKK) gives the charge Z in case of nuclear  
C fragments or residual nuclei (IDHKK(IHKK)=80000)  
C  
C NOBAM(IHKK) = 1 for particles resulting from projectile fragmentation  
C = 2 for particles resulting from target fragmentation  
C  
C IDBAM(IHKK) gives the internal dpmjet particle code (BAMJET code)

## B.2: Conventions for the scoring of the event history in /HKKEVT/

In the following we briefly characterize the subsequent entries to /HKKEVT/ together with the most important conventions for their classification.

- projectile hadron/nucleons;  
for projectile nuclei Fermi momenta in the projectile rest frame and coordinates within the nucleus are stored in the arrays PHKK and VHKK, resp., by the subroutine KKEVT;  
interacting and non-interacting nucleons have the status ISTHKK=11 and 13, resp.;  
nucleons wounded by the formation zone intranuclear cascade get status 17.
- target nucleons;  
Fermi momenta in the target rest frame and coordinates within the nucleus are defined in PHKK and VHKK, resp. (KKEVT);  
interacting and non-interacting nucleons have the status ISTHKK=12 and 14, resp.;  
nucleons wounded by the formation zone intranuclear cascade get status 18.
- valence quarks / diquarks from the interacting projectile hadron/nucleon(s) defined in the subroutine XKSAMP (total number IXPV);  
PHKK(3,...)=PHKK(4,...) contains the actual momentum fraction, VHKK the position of the 'mother' hadron;  
defined status ISTHKK=21;
- sea quarks from interacting projectile hadrons defined in XKSAMP (total number IXPS);  
PHKK(3,...)=PHKK(4,...) contains the actual momentum fraction, VHKK the position of the 'mother' hadron;  
defined status ISTHKK=31;
- valence quarks / diquarks from interacting target nucleons defined in XKSAMP (number IXTV);  
PHKK(3,...)=PHKK(4,...) contains the actual momentum fraction, VHKK the position of the 'mother' hadron;  
defined status ISTHKK=22;
- sea quarks from interacting target nucleons defined in XKSAMP (number IXTS);  
PHKK(3,...)=PHKK(4,...) contains the actual momentum fraction, VHKK the position of the 'mother' hadron;  
defined status ISTHKK=32;
- characteristics of the individual parton-parton chains (before hadronization) from subroutines KKEVVV, KKEVSV, KKEVVS and KKEVSS; for each chain there are three entries:  
(1) two entries for the quark systems forming the chain;  
PHKK gives their 4-momenta; the status of the corresponding quark system is increased by 100 as compared to the previous entry from the subroutine XKSAMP (i.e. ISTHKK=121,122,131 or 132 ,resp.);  
(2) one entry for the complete chain;  
PHKK gives the total 4-momentum, the 'particle' type for chains is defined to be IDHKK=88888;  
the actual status ISTHKK points to the chain generating subroutine:  
ISTHKK=3 for chains from KKEVVV (constructed from valence quark systems),  
ISTHKK=4 for chains from subroutine KKEVSV (sea-valence chains),  
ISTHKK=5 for chains from subroutine KKEVVS (valence-sea chains),  
ISTHKK=6 for chains from subroutine KKEVSS (sea-sea chains);
- hadrons from the hadronization of chains, entries from subroutines HADRSS, HADRVS, HADRSV, HADRVV;  
assignment of values to all arrays of /HKKEVT/, status ISTHKK=1;
- hadrons from resonance decay in JETSET or in subroutine DECHKK  
(presently called after completion of the primary interaction of the projectile treated in KKEVT);  
the status of decaying hadrons is changed to ISTHKK=2, added decay products have ISTHKK=1;
- hadrons from intranuclear cascade interactions (monitored by FOZOKL):  
the status of interacting secondary is changed to ISTHKK=2; interacting target nucleons get ISTHKK=18, final state hadrons have the status ISTHKK=1.  
Particular cases:

- (i) If a given secondary interaction is found to be forbidden because of the Pauli principle the initial state particles are stored in /HKKEVT/ with their original properties, but the actual position; so they may participate in further intranuclear interactions.
  - (ii) One (or two) nucleons from a secondary interaction cannot escape from the nuclear potential, but the particular collision is not forbidden by Pauli's principle (i.e. several nucleons knocked out of the nucleus already):  
Store the nucleon(s) with the actually generated momentum at the collision site, assigning the status ISTHKK=15 (16) for interactions in the target (projectile) nucleus. Those nucleons are available as target (projectile) nucleons in subsequent steps of the intranuclear cascade development.
  - (iii) Negative particles with energies too low to escape from the potential are forced to be absorbed within the nucleus (comp. Section 2 and Appendix); absorbed  $\pi^-$ ,  $K^-$  and  $\bar{p}$  are characterized by the status ISTHKK=19.
- Evaporation nucleons, nuclear fragments and residual target nuclei from the interface to the evaporation module.
    - (i) The excited residual nuclei before the evaporation step get ISTHKK( $i$ )=1000 and IDHKK( $i$ )=80000, the mass number A and charge Z of the nucleus are given by IDRES( $i$ ) and IDXRES( $i$ ).
    - (ii) The evaporation protons and neutrons are stored with ISTHKK( $i$ )=-1.
    - (iii) The nuclear fragments from evaporation are stored with ISTHKK( $i$ )=-1 and IDHKK( $i$ )=80000, the mass number A and charge Z of the nucleus are given by IDRES( $i$ ) and IDXRES( $i$ ).
    - (iv) The deexcitation photons are stored with ISTHKK( $i$ )=-1.
    - (v) The stable residual nuclei after the evaporation step are stored with ISTHKK( $i$ )=1001 and IDHKK( $i$ )=80000, the mass number A and charge Z of the nucleus are given by IDRES( $i$ ) and IDXRES( $i$ ).

The information from this common block allows a rather detailed reconstruction of the actual event history, and is particularly useful for consistency tests and debugging. An example is discussed in Subsection B.3.

### B.3: Sample event history from the common block /HKKEVT/

In this subsection we discuss a typical event history as stored in the common block /HKKEVT/ according to the conventions discussed in the preceding subsection B.2. The corresponding event was sampled for the interaction of a 200 GeV proton with a Sulfur nucleus. The following quantities from the common are listed for each entry: the number  $i$  of the entry, its status  $ISTHKK(i)$  and type  $IDHKK(i)$ , the pointers  $JMOHKK(2,i)$  and  $JDAHKK(2,i)$  to the 'mother' and 'daughter' particles, resp., and the array  $PHKK(5,i)$ , for final state particles containing the 4-momentum and their mass. The last 4 integers are  $IDRES(i)$ ,  $IDXRES(i)$ ,  $NOBAM(i)$  and  $IDBAM(i)$ .

The first 33 entries are made in the subroutine KKEVT for the incident proton and the 40 nucleons from the Sulfur nucleus. According to our conventions interacting hadrons get the status 11 (projectile) and 12 (target) - there are two target nucleons participating in the primary interaction (entries 2 and 25, i.e two neutrons). There are some target nucleons which got the status  $ISTHKK(i)=18$ , this are target nucleons participating in the formation zone intranuclear cascade.

1	11	2212	0	0	42	45	0.00	0.00	0.00	0.94	0.94	0	0	0	1
2	12	2112	0	0	49	52	-0.08	-0.12	-0.10	0.96	0.94	0	0	0	8
3	14	2212	0	0	108	0	0.02	0.08	-0.14	0.95	0.94	0	0	0	1
4	14	2112	0	0	0	0	0.01	-0.05	0.09	0.95	0.94	0	0	0	8
5	14	2112	0	0	0	0	-0.07	-0.06	-0.14	0.96	0.94	0	0	0	8
6	14	2212	0	0	0	0	-0.04	0.15	-0.06	0.95	0.94	0	0	0	1
7	14	2212	0	0	0	0	-0.04	0.15	0.03	0.95	0.94	0	0	0	1
8	14	2212	0	0	0	0	-0.08	0.13	0.08	0.96	0.94	0	0	0	1
9	14	2212	0	0	0	0	-0.03	0.11	0.01	0.95	0.94	0	0	0	1
10	14	2212	0	0	0	0	0.09	0.05	0.13	0.95	0.94	0	0	0	1
11	14	2112	0	0	0	0	0.12	0.04	-0.04	0.95	0.94	0	0	0	8
12	14	2112	0	0	0	0	-0.04	0.15	0.05	0.95	0.94	0	0	0	8
13	14	2112	0	0	0	0	-0.08	0.00	-0.13	0.95	0.94	0	0	0	8
14	18	2112	0	0	92	95	-0.09	-0.02	-0.02	0.94	0.94	0	0	0	8
15	14	2212	0	0	0	0	0.13	-0.09	0.05	0.95	0.94	0	0	0	1
16	14	2212	0	0	0	0	0.02	-0.09	0.12	0.95	0.94	0	0	0	1
17	14	2112	0	0	0	0	0.05	0.03	0.02	0.94	0.94	0	0	0	8
18	18	2212	0	0	96	97	0.08	-0.05	-0.03	0.94	0.94	0	0	0	1
19	18	2112	0	0	102	103	0.10	0.08	-0.09	0.95	0.94	0	0	0	8
20	14	2212	0	0	0	0	-0.06	0.11	0.14	0.96	0.94	0	0	0	1
21	14	2112	0	0	0	0	0.08	-0.03	-0.08	0.95	0.94	0	0	0	8
22	18	2112	0	0	104	105	-0.11	0.04	0.01	0.95	0.94	0	0	0	8
23	14	2212	0	0	0	0	-0.12	-0.01	0.04	0.95	0.94	0	0	0	1
24	14	2112	0	0	0	0	-0.16	-0.07	0.01	0.96	0.94	0	0	0	8
25	12	2112	0	0	43	46	0.01	-0.05	0.14	0.95	0.94	0	0	0	8
26	18	2112	0	0	90	91	0.00	-0.13	-0.13	0.96	0.94	0	0	0	8
27	14	2112	0	0	0	0	0.08	-0.01	0.01	0.94	0.94	0	0	0	8
28	18	2212	0	0	106	107	-0.10	-0.15	0.07	0.96	0.94	0	0	0	1
29	14	2212	0	0	0	0	0.06	0.02	0.16	0.95	0.94	0	0	0	1
30	14	2112	0	0	0	0	0.13	-0.03	-0.08	0.95	0.94	0	0	0	8
31	18	2212	0	0	98	101	0.03	-0.03	-0.15	0.95	0.94	0	0	0	1
32	14	2212	0	0	0	0	0.10	0.02	0.13	0.95	0.94	0	0	0	1
33	14	2212	0	0	0	0	0.01	-0.15	-0.11	0.96	0.94	0	0	0	1

The next entries come from the subroutines XKSAMP and FLKSAM (in module DPMNUC3) assigning  $x$  values and flavor to the quarks participating in the interaction: The projectile proton is split into a  $d$  valence quark, an valence diquark ( $uu$ ) (both with status  $ISTHKK=21$ ), and two quarks  $d$  and  $\bar{d}$  from a colorless sea pair (status  $ISTHKK=31$ ). The interacting target nucleons are split in valence quark-diquark systems: the neutron (entry 2) into  $d$ -( $ud$ ), the neutron (entry 25) into  $d$ -( $ud$ ). The  $x$  values given for each quark system as  $PHKK(3,i)=PHKK(4,i)$  add up to one for each individual hadron.

34	21	1	1	0	48	48	0.00	0.00	0.18	0.18	0.00	0	0	0	391
35	21	2203	1	0	51	51	0.00	0.00	0.32	0.32	0.00	0	0	0	410
36	31	1	1	0	42	42	0.00	0.00	0.01	0.01	0.00	0	0	0	391
37	31	-1	1	0	45	45	0.00	0.00	0.50	0.50	0.00	0	0	0	392

38	22	1	2	0	52	52	0.00	0.00	0.13	0.13	0.00	0	0	0	391
39	22	2103	2	0	49	49	0.00	0.00	0.87	0.87	0.00	0	0	0	410
40	22	1	25	0	46	46	0.00	0.00	0.11	0.11	0.00	0	0	0	391
41	22	2103	25	0	43	43	0.00	0.00	0.89	0.89	0.00	0	0	0	410

The following entries come from the routines constructing the colorless parton-parton chains. First the chains are considered (in subroutine KKEVSV) which are composed from projectile sea quarks and target valence quarks. In this example there are two such chains:  $d$ -( $ud$ ) and  $\bar{d}$ - $u$ . The entries are made subsequently for the partons forming the chain and the constructed chain itself, with the array PHKK(5, $i$ ) containing the corresponding 4-momenta and the mass, resp. The 4-momenta are defined in the cms system of the incident hadron and a single nucleon (without Fermi momentum). By definition these chains get the status ISTHKK=4, the status of quarks/quark systems at chain ends is increased by 100 compared to their previous entries.

Please note: quarks, diquarks and chains have no BAMJET code, therefore the last entry in the line (IDBAM( $i$ )) picks up values without significance

42	131	1	36	1	44	44	-0.06	-0.10	0.02	0.19	0.00	0	0	0	391
43	122	2103	41	25	44	44	0.03	-0.03	-7.36	7.41	0.00	0	0	0	410
44	4	88888	42	43	54	57	-0.03	-0.13	-7.34	7.59	1.94	0	0	0	0
45	131	-1	37	1	47	47	-0.03	0.00	-0.05	0.96	0.00	0	0	0	392
46	122	1	40	25	47	47	0.23	-0.07	3.90	4.84	0.00	0	0	0	391
47	4	88888	45	46	58	67	0.20	-0.07	3.86	5.80	4.33	0	0	0	0

In the same manner the next entries describe the chains constructed from valence quark systems of both the projectile and a target nucleon (neutron in this example) in the subroutine KKEVVV. Entries for all chains are marked by the identity IDHKK=88888, valence-valence chains get the status ISTHKK=3.

48	121	1	34	1	50	50	-0.15	-0.02	1.54	1.72	0.00	0	0	0	391
49	122	2103	39	2	50	50	0.17	-0.11	-9.25	9.43	0.00	0	0	0	410
50	3	88888	48	49	68	81	0.03	-0.13	-7.71	11.15	8.05	0	0	0	0
51	121	2203	35	1	53	53	-0.25	-0.01	-1.15	1.45	0.00	0	0	0	410
52	122	1	38	2	53	53	-0.13	-0.26	2.75	3.07	0.00	0	0	0	391
53	3	88888	51	52	82	89	-0.38	-0.27	1.59	4.53	4.21	0	0	0	0

The next entries are generated by the routines HADRxx monitoring the chain decay.

First the decay of the (two) sea-valence chains is handled via HADRSV. With ISTHKK( $i$ )=1 we find the final stable hadrons, with ISTHKK( $i$ )=2 we find the resonances, which have decayed already within the JETSET fragmentation code. The stable hadrons resulting from resonance decay point to the decaying resonance (IMOHKK(1, $i$ )). Also stable hadrons might have ISTHKK( $i$ )=2, in this case they have interacted subsequently in the formation zone cascade.

After event completion the 4-momenta are given in the laboratory system.

54	1	-211	44	0	0	0	0.25	-0.59	0.69	0.95	0.14	0	0	0	14
55	2	2214	44	0	0	0	-0.28	0.46	1.55	2.02	1.17	0	0	0	54
56	1	2212	55	0	0	0	-0.07	0.38	1.30	1.65	0.94	0	0	2	1
57	1	111	55	0	0	0	-0.21	0.07	0.22	0.34	0.13	0	0	2	23
58	2	223	47	0	0	0	0.20	-0.04	7.99	8.03	0.79	0	0	0	35
59	1	-211	47	0	0	0	0.55	-0.20	5.85	5.88	0.14	0	0	2	14
60	1	211	47	0	0	0	0.10	-0.15	12.38	12.38	0.14	0	0	2	13
61	2	113	47	0	0	0	-1.00	0.41	47.65	47.67	0.69	0	0	0	33
62	1	111	47	0	0	0	0.35	-0.09	25.78	25.78	0.13	0	0	2	23
63	1	211	58	0	0	0	0.13	0.26	2.42	2.44	0.14	0	0	2	13
64	1	-211	58	0	0	0	0.13	-0.08	2.36	2.37	0.14	0	0	2	14
65	1	111	58	0	0	0	-0.06	-0.22	3.21	3.22	0.13	0	0	2	23
66	1	211	61	0	0	0	-0.54	-0.12	20.43	20.44	0.14	0	0	2	13
67	1	-211	61	0	0	0	-0.45	0.52	27.22	27.23	0.14	0	0	2	14
68	2	221	50	0	0	0	0.06	-0.36	20.51	20.52	0.55	0	0	0	31
69	2	223	50	0	0	0	0.48	0.02	6.32	6.38	0.78	0	0	0	35
70	2	113	50	0	0	0	0.01	0.48	8.05	8.11	0.77	0	0	0	33
71	1	-211	50	0	0	0	-0.64	0.44	0.79	1.11	0.14	0	0	0	14
72	1	2212	50	0	0	0	0.11	-0.69	1.24	1.70	0.94	0	0	0	1
73	1	-211	68	0	0	0	0.07	-0.12	9.17	9.17	0.14	0	0	2	14



74	1	211	68	0	0	0	0.10	-0.15	4.20	4.20	0.14	0	0	2	13
75	1	-11	68	0	0	0	-0.06	-0.08	2.68	2.68	0.00	0	0	0	4
76	1	11	68	0	0	0	-0.05	-0.01	4.46	4.46	0.00	0	0	0	3
77	2	211	69	0	90	91	0.25	0.28	3.43	3.46	0.14	0	0	0	13
78	1	-211	69	0	0	0	0.16	-0.18	1.06	1.10	0.14	0	0	2	14
79	1	111	69	0	0	0	0.07	-0.08	1.77	1.78	0.13	0	0	2	23
80	1	-211	70	0	0	0	-0.10	0.51	4.90	4.93	0.14	0	0	0	14
81	1	211	70	0	0	0	0.12	-0.03	1.28	1.30	0.14	0	0	2	13
82	2	-213	53	0	0	0	-0.20	0.21	15.88	15.90	0.77	0	0	0	34
83	2	213	53	0	0	0	0.39	-0.23	4.51	4.60	0.77	0	0	0	32
84	2	111	53	0	92	95	-0.49	-0.36	8.47	8.50	0.13	0	0	0	23
85	1	2212	53	0	0	0	-0.09	0.11	34.73	34.74	0.94	0	0	2	1
86	1	-211	82	0	0	0	-0.42	0.07	13.24	13.25	0.14	0	0	2	14
87	1	111	82	0	0	0	0.22	0.14	2.94	2.96	0.13	0	0	2	23
88	2	211	83	0	96	97	0.39	0.02	1.25	1.31	0.14	0	0	0	13
89	2	111	83	0	98	101	0.01	-0.26	2.44	2.46	0.13	0	0	0	23

Next we find the entries from the formation zone cascade in subroutine FOZOKL. The status of the initial state target nucleon is changed to ISTHKK=18.

In some of the entries we find the status code ISTHKK(i)=16. This are nucleons from secondary interactions not able to escape from the nucleus. These nucleons are available as targets for subsequent collisions.

90	1	211	77	26	0	0	0.95	1.04	1.96	2.42	0.14	0	0	0	13
91	1	2112	77	26	0	0	-0.69	-0.87	1.31	1.96	0.94	0	0	0	8
92	2	111	84	14	102	103	0.11	0.12	0.12	0.24	0.13	0	0	0	23
93	1	2112	84	14	0	0	-0.05	-0.06	0.07	0.95	0.94	0	0	0	8
94	1	-211	84	14	0	0	-0.62	-0.37	7.82	7.86	0.14	0	0	0	14
95	1	211	84	14	0	0	0.04	0.00	0.32	0.36	0.14	0	0	0	13
96	1	211	88	18	0	0	0.79	0.01	0.91	1.22	0.14	0	0	0	13
97	2	2212	88	18	104	105	-0.33	-0.04	0.30	1.04	0.94	0	0	0	1
98	1	-211	89	31	0	0	0.64	-0.10	0.56	0.87	0.14	0	0	0	14
99	1	211	89	31	0	0	-0.15	-0.11	-0.04	0.24	0.14	0	0	0	13
100	1	2112	89	31	0	0	-0.25	0.01	0.64	1.16	0.94	0	0	0	8
101	1	211	89	31	0	0	-0.19	-0.09	1.07	1.10	0.14	0	0	0	13
102	1	111	92	19	0	0	-0.07	0.10	-0.09	0.20	0.14	0	0	0	23
103	1	2112	92	19	0	0	0.19	0.07	0.08	0.96	0.94	0	0	0	8
104	16	2212	97	22	0	0	-0.11	-0.10	0.03	0.95	0.94	0	0	0	1
105	2	2112	97	22	106	107	-0.32	0.10	0.28	1.04	0.94	0	0	0	8
106	16	2112	105	28	108	0	-0.05	0.08	0.21	0.97	0.94	0	0	0	8
107	1	2212	105	28	0	0	-0.29	-0.10	0.11	0.99	0.94	0	0	0	1

The final entries in the COMMON block refer to the evaporation step of the excited residual target nucleus. With status code ISTHKK(i)=1000 we find the excited residual nucleus. Evaporation nucleons, deexcitation photons and nuclear fragments follow with status code ISTHKK(i)=-1 and the stable residual nuclei follows with status code ISTHKK(i)=1001.

1081000	80000	3	106	109	119	-0.09	0.32	0.67	23.43	23.42	25	14	0	0	
109	-1	2112	108	0	0	0	-0.01	-0.03	-0.08	0.94	0.94	0	0	2	8
110	-1	2212	108	0	0	0	-0.07	-0.02	0.04	0.94	0.94	0	0	2	1
111	-1	2212	108	0	0	0	0.07	0.15	-0.10	0.96	0.94	0	0	2	1
112	-1	2212	108	0	0	0	-0.08	0.05	-0.02	0.94	0.94	0	0	2	1
113	-1	2212	108	0	0	0	0.01	0.05	0.03	0.94	0.94	0	0	2	1
114	-1	2212	108	0	0	0	0.04	0.01	0.05	0.94	0.94	0	0	2	1
115	-1	22	108	0	0	0	0.00	0.00	0.00	0.00	0.00	0	0	2	7
116	-1	80000	108	0	0	0	-0.09	-0.23	0.10	3.74	3.73	4	2	2	0
117	-1	80000	108	0	0	0	0.06	0.09	0.27	3.74	3.73	4	2	2	0
118	-1	80000	108	0	0	0	0.16	0.13	0.04	3.73	3.73	4	2	2	0
1191001	80000	108	0	0	0	-0.18	0.13	0.33	6.55	6.54	7	3	2	0	

Eventually the actual final state hadrons, photons and nuclei are obtained from the common block /HKKEVT/ by picking up all particles with the status ISTHKK=1, ISTHKK=-1 and ISTHKK=1001.

## APPENDIX C : FURTHER OPTIONS FOR INTERNAL USE

- Code word = 'PAULI'

This option monitors the inclusion of Pauli's principle for the intranuclear cascade.

**WHAT(1)** : Pauli principle active for 1.0 (default)

**WHAT(2)** : triggers test prints for debugging if greater than 0.0;  
default : 0.0, i.e. no additional printout.

- Code word = 'INTPT'

This option monitors the additional sampling of transverse momenta for partons;

**WHAT(1)** : 1.0 activates the sampling of parton  $p_t$  values (default).

- Code word = 'TECALBAM'

This option triggers tests of the hadronization routines; additional input cards are required (see subroutine TECALB), to be given immediately after the code word definition; WHAT parameters have no meaning.

- Code word = 'HADRIN'

Via this option the secondary interactions generated from FHAD may be forced to be all inelastic/elastic ones.

**WHAT(1)** = 0 : inelastic/elastic as monitored by FOZOKL  
1 : inelastic collisions forced  
2 : elastic collisions forced.

- Code word = 'OUTLEVEL'

This option monitors the printout of intermediate results for diagnostics;

**WHAT(I) ≥ 1**: diagnostics for remaining minor problems is printed (mainly consistency/ accuracy problems in kinematical calculations).

- Code word = 'INFOREJE'

This option monitors the printout of rejection information

**WHAT(I) = 1**: rejection information is printed.

- Code word = 'RECOMBIN'

Combinatoric transformation of s-s and v-v chains into s-v and v-s chains

**WHAT(1)** = 0 no recombination,  
What(1) = 1 recombination implemented.  
Default: 0.

- Code word = 'CMHISTO'

The events in COMMON HKKEVT are sampled in the CMS frame

**WHAT(1)** = 0 sampling in lab frame,  
What(1) = 1 sampling in CMS frame  
Default: 0.

Note: If WHAT(1)=1 there is no possibility to treat the formation zone cascade. See cards TAUFOR and PROJKASK

- Code word = 'FLUCTUAT'

implement cross section fluctuation (see Ref. [21-23])

**WHAT(1)** = 0 no fluctuations,  
What(1) = 1 fluctuations implemented.  
Default: 0.

## APPENDIX D : FURTHER OPTIONS FROM THE DTUJET-99 CODE WITHIN DPMJET

- Code word: STRUCFUN

Defines the structure functions used in the sampling of hard constituent scattering [24-26] .

**WHAT(1):** = ISTRUF

ISTRUF = 21 : Glueck,Reya,Vogt with K = 1: GRV94LO

ISTRUF = 22 : Glueck,Reya,Vogt with K = 2: GRV98LO

ISTRUF = 23 : CTEQ Collaboration (1996): CTEQ96

ISTRUF = 221,222,223 : as above with energy dependent  $p_{\perp}$  threshold value

The default is 222 . Only for this structure function we have a new fit. Therefore the use of STRUCFUN with ISTRUF different from 222 is not recommended in DPMJET-II.5.

An energy dependent cutoff [5] avoids a hard scattering cross section too large to be treated in our simple eikonal approximation. To use this new option the number 200 has to be added to the chosen ISTRUF value.

- Code word: PSHOWER

This card determines whether hard partons initiate showers in connection with JETSET fragmentation.

**WHAT(1):** = IPSHOW

IPSHOW = 0 : Generation of hard parton showers suppressed.

IPSHOW = 1 : Hard parton showers are included.

The default is 1.

- Code word: GLUSPLIT

Prevents splitting of gluons into quark-antiquark pairs.

**WHAT(1):** = NUGLUU, Default: 1

NUGLUU=1 : Only one jet in hard gluon scattering.

Recommended: NUGLUU=1.

**WHAT(2):** = NSGLUU, Default: 0

NSGLUU=0 : Two jets in soft sea gluon jets.

NSGLUU=1 : Only one jet in soft sea gluon jets.

Recommended: NSGLUU=0.

- Code word: SIGMAPOM

Defines options and/or demands a test run for the calculation of the DTU model unitarizing the soft and hard hadronic cross sections. The test run is for calculating the total and inelastic cross sections as functions of the collision energy as well as initializing and testing the sampling of multi-Pomeron events at some typical energies. Without the test run only the initialization at the energy defined in the run is done.

**WHAT(1):** = ITEST, test run for ITEST = 1.

**WHAT(2)** = ISIG, characterizes the soft and hard input cross sections for the unitarization (see SUBROUTINE SIGSHD).

Recommended and default and only remaining option in DPMJET-II.5 : ISIG = 10

**WHAT(3)** = IPIM characterizes the method to calculate the distribution in the number of soft  $n_s$  and hard  $n_h$  Pomerons

Default and recommended and only remaining option in DPMJET-II.5: IPIM = 482

**WHAT(4)** = LMAX Default: 30

LMAX : Maximum considered number of soft Pomerons (Less than 26).

**WHAT(5)** = MMAX Default: 100

MMAX : Maximum considered number of hard Pomerons (Less than 101).

**WHAT(6)** = NMAX Default: 2

NMAX : Maximum considered number of triple-Pomerons (Less than 13).